THE LACRIMAL SYSTEM

Clinical Application

EVERETT R. VEIRS

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GRUNE & STRATTON

NEW YORK AND LONDON 1955

Library of Congress Catalog Card Number 55-11144

Printed and bound in U.S.A.

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Preface

During the past half century, a wealth of information has been gained concerning the lacrimal system. About fifty years ago, Toti published his technic of establishing an anastomosis between the lacrimal sac and the nose, and this stimulated an intense interest in the lacrimal drainage system. During the period since that time, much has been learned concerning the anatomy, embryology, physiology and pathology of the entire system.

Advances have been rapid in the diagnosis and treatment of many lacrimal disorders. Extirpation of the lacrimal sac, once a common operation, now seldom can be justified. Knowledge concerning the diagnosis, prognosis and treatment of tumors of the lacrimal gland has made rapid strides.

Formerly, the various components of the lacrimal system have been treated, for the most part, as separate, unrelated entities. Although many excellent treatises have been published on various phases of the subject, there has been no publication available which covered the entire field. An attempt has been made here to present, in monograph form, information concerning the entire lacrimal system. It was the idea of the author to make his book as practical as possible. Stress has been given to the treatments and operations that have stood the test of time. Because illustrations and photographs often easily tell so much more than words, these have been used freely. No attempt at a complete bibliography has been made. There is a legitimate overlapping of interest in this subject for the ophthalmologist, the otolaryngologist, the general practitioner and the pediatrician.

I am indebted especially to my good friend Dr. J. V. Cassady, who contributed the chapter on developmental anatomy. Without the help of Mr. Kenneth G. Phillips, who did the illustrations, and Mr. Leroy Winburne, who did the photographic work, this book would not have been possible. I am indebted also to Miss Letha Easterwood for the editing of the manuscript and to Miss Edrene Wallace and Mrs. Martha Robinson for their untiring work in its preparation.

E. R. V.

Acknowledgments

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Physiology and Pathologic Physiology of the Lacrimal System

A. PHYSIOLOGY OF THE LACRIMAL SYSTEM

Tear Secretion

TEARS are secreted by the lacrimal gland and the accessory lacrimal glands (glands of Wolfring and Krause). These accessory glands are scattered widely throughout the conjunctiva and under normal circumstances secrete sufficient tears for the proper functioning of the eyes. Some authorities believe that most of the tears are secreted by the accessory lacrimal glands and that the lacrimal gland itself secretes tears chiefly when there is profuse tearing such as from emotional states, corneal irritations, and other causes.

In addition to the lacrimal glands, and probably of equal importance, are the sebaceous and mucous glands of the conjunctiva. The sebaceous glands, which consist of the meibomian glands and the glands of Zeis, secrete an oily fluid. The numerous goblet cells within the conjunctiva secrete mucus, which serves a vital purpose. The oily secretion, chiefly from the meibomian glands, has several functions. As oil protects the skin, the oil here protects the lid margins not only from drying but also from maceration from tears. In addition, tears are prevented from overflowing upon the cheek by an oily film strip which these glands secrete.

Loewenberg[16] divides lacrimal gland stimulation into "reflectory" and "emotional." Reflectory, or reflex, stimulation is that which the gland receives for normal wetting and irrigation of the eye. Tearing that results from mechanical and chemical irritation or reflex stimulation from vomiting, sneezing and similar actions is considered in this category. It is probable that the diminished tearing sometimes seen following dacryocystectomy is attributable to the abolition of reflex stimulation of the lacrimal gland. An infected lacrimal sac with its accompanying conjunctivitis almost certainly causes increased stimulation and secretion of tears. The hypothalamus is considered the center for psychogenic stimulation of tears, which results in such emotional reactions as crying or joyful outbursts. Infants do not shed tears during their first few weeks

of life, even though they may cry prodigiously. It is said that animals that live in air possess lacrimal glands and hence shed tears.

Summerskill[35] stresses the importance of tearing in the aged resulting from central degenerative changes. This type of tearing is termed neuropathic. Frequent wiping of the eyes in these individuals may be the cause of ectropion, not ectropion the primary cause of epiphora.

The parasympathetic stimulants such as pilocarpine cause an increased formation of tears, whereas the parasympathetic depressants such as atropine check the secretion of tears.

According to Maes,[19] the removal of the superior cervical ganglion in cats causes an increase in sensitivity of the lacrimal gland to acetylcholine, pilocarpine and Adrenalin. This increase in sensitivity, however, is not evident until about eleven days after the ganglion has been removed.

The fifth cranial nerve carries the afferent nerve fibers. Lacrimation results when this nerve is stimulated. The efferent nerve fibers apparently run in the seventh cranial nerve by way of the greater superficial petrosal nerve and the sphenopalatine ganglion (fig. 1).

A greater superficial petrosal neurectomy has been effective in relieving lacrimation in severe chronic bullous keratitis, as reported by Nosik and Johnson.[24] Pain subsides and vision improves after this procedure. A

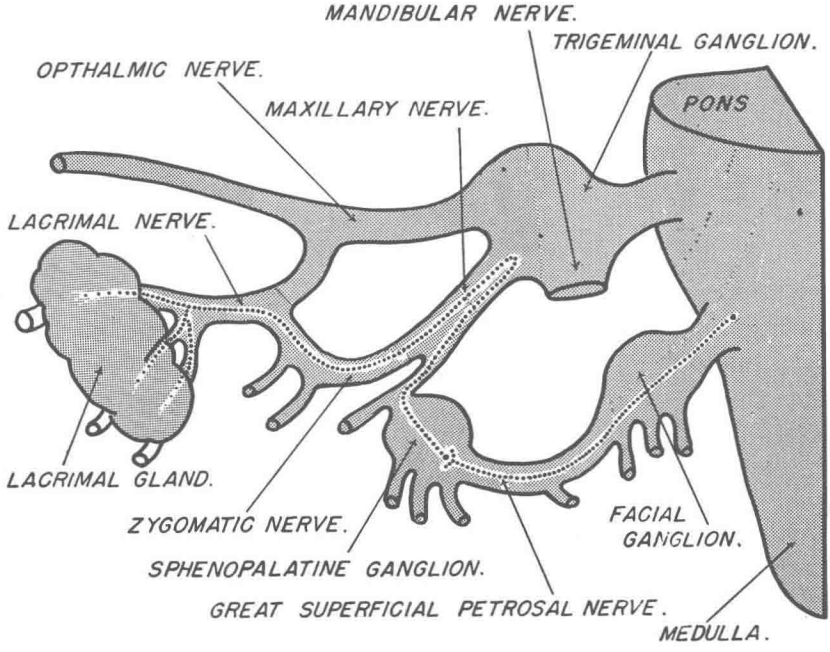

FIG. 1.—Diagram showing the efferent pathway of the lacrimation reflex. (After Mutch.)

deep corneal lesion, by and large, causes less tearing than one of superficial type. Small foreign bodies in the cornea usually cause profuse lacrimation. No increase in lacrimation occurs with corneal lesions, such as ulcers, when there is corneal anesthesia. An example of this is seen after removal of a neuroma of the eighth nerve, in which corneal anesthesia and exposure keratitis are common.

Quantity of Tears Secreted

The quantity of tears secreted in a 24-hour period cannot be measured accurately, but it has been estimated at about 1 cc. or less. Evaporation accounts for the disappearance of approximately half of the amount of tears secreted. The remainder normally drains through the lacrimal sac down into the nose. There is very little secretion of tears during sleep. The quantity of tears secreted by the normal glands can be increased by administration of sudorific drugs such as pilocarpine. When the lacrimal glands are diseased, as in keratoconjunctivitis sicca, these drugs have little, if any, effect. Parasympatholytic drugs such as atropine diminish the secretion of tears. The quantity of tears may be increased very greatly by reflex stimulation of the eye such as occurs with irritation of the eyes from corneal lesions. The afferent nerve that carries this stimulation is the ophthalmic division of the trigeminal nerve. The efferent fibers of the lacrimal gland presumably are carried in the facial nerve and pass along the greater superficial petrosal nerve to form synapsis in the sphenopalatine ganglion. Psychic disturbances increase the secretion of tears, always bilaterally. Psychic response is dependent only upon the efferent fibers and hence is possible if the ophthalmic nerve is severed. The sympathetic, as well as the parasympathetic, probably plays a part in the secretion of tears.

Characteristics of Tears

Osmotic concentration. Considerable variation in the osmotic concentration of tears has been noted by various investigators. This concentration has been found to equal that of approximately 1.4 per cent sodium chloride. In order that there may be no discomfort to the patient, drops used in the eye should have a concentration within or close to this level.

Hydrogen ion concentration. The pH of tears also varies, not only among different individuals but also at different times with the same individual. Usually, tears are slightly alkaline and have a pH range of 7 to 7.5. Ophthalmic solutions with pH in this range afford greatest comfort, especially if there is buffering.

Composition. The following table shows the composition of tears as determined by Ridley.[26]

SUBSTANCE	PERCENTAGE
Total solids	1.8
Ash	1.05
Total protein	0.669
Albumin	0.394
Globulin	0.275
Nonprotein nitrogen	0.051
Total nitrogen	0.158
Urea	0.04
Sugar	0.065
Na_2O	0.6
K_2O	0.14
NH_3	0.003
Chlorine	0.394
NaCl	0.65

Function of Tears

Moistening of the eye. Keeping the eye moist is possibly the most important function of tears, which constitute one of the fluids that come to form the precorneal film. The strip of tears along each lid margin moves with the lid margins across the cornea. The precorneal film contains not only tears but mucus from the conjunctival glands and oily fluid from the meibomian glands. According to Wolff,[36] the precorneal film consists of the following parts:

THE MUCOID LAYER. This is the deepest layer. Its composition is very much like that of the cornea itself.

THE TEARS. The tears form the middle layer and help to lubricate and moisten the eyeball to prevent drying of the corneal epithelium. In addition, tears wash foreign particles and irritating fumes from the cornea.

THE OILY FILM. The oily film lies most superficially. The purpose of this film is not only to help lubricate and to prevent tears from flowing down over the cornea but also to delay the evaporation of the tear layer. Actually, although there are three components of the precorneal film, these are not completely distinct layers but are to some extent mixed.

Importance in the dioptric system of the eye. The tears, along with the other components of the precorneal film, play a very vital role in the dioptric system of the eye. This smooth, moist film is continuously present, and without it one would be greatly handicapped so far as vision is concerned.

Bacteriostatic effect. Tears contain an enzyme called lysozyme, first described by Fleming[7] in 1922. This lysozyme is believed to give protection against bacterial infections by hydrolyzing a mucoid substance found

in the walls of many bacteria. Regan[25] found that the lysozyme content of tears usually diminished in pathologic conditions associated with excessive tearing as well as in corneal dystrophy and keratoconjunctivitis sicca. It seems likely that the lysozyme content of tears may be diminished by the use of antiseptic drops in the conjunctival sac. Two other factors tend to make tears a relatively poor culture medium for pathogenic organisms. One is the low amount of reducing substance of tears, which has been measured by Giardini and Roberts.[10] The true glucose in tears, which is present to the extent of 2.4 mg. per 100 mm., represents only 41 per cent of the total reducing substance. The second factor that discourages growth of pathogenic organisms is the lowered temperature in the conjunctival sac resulting from the evaporation of tears.

According to Markovitch,[20] the temperature on the surface of the cornea is 30 C., whereas the optimal temperature for growth of pathogenic bacterial substances is between 35 C. and 38 C. The bacterial flora of the eye usually increases with prolonged closure of the eye, as in sleep or when an eye is bandaged. Other factors besides increased temperature operate in a closed eye to promote this growth; for example, the absence of the mechanical washing of tears. The presence of antibiotic bacteria in the conjunctival sac, according to Halbert and Swick,[12] assists also in the job of keeping pathogenic bacteria under control. According to these authors, the organisms are chiefly of the genus Micrococcus. They found also a striking analogy between the antibiotic bacteria of the eye and those of the intestinal tract.

Tear Drainage

Flow within the conjunctival sac. The exact direction of the flow of tears within the conjunctival sac is unknown. The greatest collections of tears are to be found at the inner and outer canthi and at the juncture of the posterior lid margins and the eyeball. In the normal eye, there is always a strip of tears running the length of both upper and lower eyelids. This strip is between the inner lid margin and the eyeball. The tears extend onto the eyeball as much as a millimeter or more. Most of the tear ducts from the lacrimal glands open into the outer half of the upper cul-de-sac, though some open into the outer portion of the lower cul-de-sac. Most of the tears probably find their way to the lacrimal puncta by way of the strips along the lid margins. Tears from the upper conjunctivas may reach the lower conjunctivas by (1) passage downward at the outer and inner canthi or (2) direct flow downward of the tears over the cornea during opening and closing of the eyelids.

It is estimated that the amount of tears secreted within a 24-hour period is not over 1 cc., and about half of this amount is lost through evaporation; but, even so, the proper drainage of tears is of considerable

importance. The annoyance of blurred vision from excessive tears in the conjunctival sac, together with epiphora, is great.

Tears normally are prevented from overflowing from the lids by the oily secretion from the meibomian gland. This oily film traps the tears in a strip between the posterior lid margin and the globe. The puncta dip backward into this strip of tears.

The orbicularis oculi plays a vital part in the drainage of tears from the conjunctival sac to the nose. Adequate proof of this is that patients with partial paralysis of the seventh cranial nerve have epiphora though the puncta may be in their normal positions. On closure of the eyelids, the puncta are drawn 2 or 3 mm. toward the inner canthus.

Tears enter the canaliculi through the puncta at least partly by capillarity. If the puncta are dilated too widely or are slit, this capillarity is interfered with and tear drainage is less efficient. There can be no doubt that the canaliculi shorten appreciably when the orbicularis oculi contracts. With this shortening of the canaliculi, there is most likely increase in the diameters. The canaliculi have a rich supply of elastic tissue, which allows normal variation in the volume of the canaliculi. Rosengren and Kugelberg,[29] in a carefully controlled experiment, demonstrated the movement of fluid within the canaliculi during closure of the lid. Regurgitation is prevented, they felt, by the increased pressure in the conjunctival sac from the closure of the lid.

Although the punctum may be normal, tear drainage may be poor in a patient with a dilated lower canaliculus. This dilatation is seen after involvement of the canaliculus with Streptothrix.

The flow of tears from the lacrimal sac into the nose is helped by gravity. There is some question as to how much the sac varies in volume because of the contraction of the orbicularis oculi, including Horner's part of the muscle. First, the lacrimal sac has little, if any, elastic element. Second, the sac is enclosed to a considerable extent in a bony fossa, with the outer part of the sac covered tightly by the lacrimal fascia. Nevertheless, there is most likely some variation in the volume of the sac, especially of its upper third, with contraction and dilation of the orbicularis oculi. Adler[1] states that, on closure of the lid, the upper part of the sac becomes distended with the result that fluid is drawn into the sac from the canaliculi. At the same time, the lower portion of the sac becomes compressed by reason of the fact that the fibers of the orbicularis oculi expel the fluid in this portion of the sac into the nose. Because of the rich blood supply in and around the sac, variations in the volume of the sac could occur, as the volume of blood in this region varies. Fuchs' observation that atonic sacs drain poorly though the nasolacrimal duct is patent supports the view that emptying of the sac is dependent upon more than mere gravity.

Milder and Demorest[22] demonstrated by injection of ethyl iodophenylundecylate (Pantopaque) that the normal lacrimal sac shows little, if any, evidence of emptying at the end of 15 minutes. The same sac was either completely or almost empty at the end of 30 minutes.

B. PATHOLOGIC PHYSIOLOGY OF THE LACRIMAL SYSTEM

Secretory Disorders

Hypersecretion of tears. Lacrimation and epiphora should be differentiated. Epiphora is defined as abnormal overflow of tears over the lids, usually because of a deficiency in the drainage mechanism. Although lacrimation is thought of generally as excessive secretion of tears, it is technically the secretion of tears regardless of the amount.

CAUSES:

1. Psychological. Hypersecretion of tears resulting from emotional states such as crying or joyous outbursts is a very common and normal condition, though weeping may be pronounced in mentally disturbed patients.

2. Reflex. Stimulation, especially that from pain, is perhaps the most frequent cause of excessive secretion of tears. Most irritative lesions of the eye cause lacrimation, especially superficial corneal ones such as foreign bodies. Many irritants such as fumes, dust, and excessive light cause increased secretion of tears. Stimulation of the nasal mucosa usually causes a profuse secretion of tears.

3. Neuropathic. There are numerous examples of the neuropathic type of weeping. Summerskill[35] stresses the fact that many elderly people have this "weepy" type of hypersecretion. Their frequent wiping of the eyes leads to eversion of the punctum and conjunctivitis. Irritative lesions along the efferent pathway of the lacrimal reflex cause excessive secretion of tears.

Crocodile tears or paradoxical weeping may occur in patients who have had an incomplete recovery from Bell's palsy. Bogorad,[3] in 1926, used the term "crocodile tears" since the crocodile formerly was thought to weep hypocritical tears while devouring its victims, though most authors writing on this subject do not believe that animals shed tears as the result of emotional states. Approximately 20 per cent of patients with Bell's palsy have incomplete recovery, and, according to Duel,[5] 80 per cent of those that have had incomplete recovery show crocodile tears. This percentage is probably high. Shedding of crocodile tears occurs on the paralyzed side during mastication and begins a few weeks after the onset of facial paralysis. This is not to be confused with epiphora resulting from weakness of the orbicularis oculi muscle, which occurs early in Bell's palsy.

This phenomenon probably occurs because the new axons in the degenerated nerve find the wrong path during the process of regeneration. Most likely, the nerve fibers which normally would approach the salivary glands to stimulate secretion are diverted and reach the lacrimal gland instead. It is stimulation of the taste buds on the homolateral side, rather than stimulation of the muscles of mastication, that induces the tears.

4. Miscellaneous. There are many miscellaneous causes for hypersecretion of tears such as those that occur because of (1) disturbances of the lacrimal gland, (2) use of parasympathomimetic drugs such as pilocarpine or Mecholyl, and (3) certain diseases such as lues of the central nervous system and toxic goiter. Excessive secretion of tears is especially frequent in the thyrotropic type of exophthalmus. During a period of five seconds, a patient with this type of exophthalmus, treated by the author, had wetting of 25 mm. of No. 41 Whatman filter paper. Part of this, of course, represented an excess of tears already in the conjunctival sac. Tears (.162 Gm.) were collected in both eyes in a period of fifteen minutes. The excessive tears within the conjunctival sacs were removed with filter paper before the starting of the tear collection for measurement.

TREATMENT. The cause of hypersecretion of tears usually is not too difficult to find. Diseases of the cornea, trichiasis, and refractive errors should be looked for and proper corrective measures taken. Intranasal pathologic conditions may have to be corrected. Careful examination of the lacrimal drainage system must be made. What seems to be excessive tearing may be due to an everted lower punctum. The paradoxical or crocodile weeping tends to diminish with time. Gottesfeld and Leavitt[11] stopped this type of tearing for a period of four and one-half months by injection of 0.5 cc. of alcohol (95 per cent) into the sphenopalatine ganglion by way of the posterior palatine foramen.

Severing of the ductules of the lacrimal gland usually is not indicated but may be used in instances of persistence of hypersecretion as well as in cases of epiphora due to obstruction to the lacrimal drainage. After the ductules are severed, the tears secreted by the lacrimal gland cannot reach the conjunctival sac, and the gland probably atrophies to some extent. This is not entirely true, as probably not all the ductules are severed. If it is desired to cut down moderately on tear secretions, only part of the ductules need be severed.

The essential features of this operation, described by Jameson,[15] are as follows: The incision is made in the palpebral conjunctiva 2 or 3 mm. below the outer canthus. With the upper lid everted, the points of a pair of Stevens scissors are inserted into the incision and carried upward and medially, separating the palpebral conjunctiva in the outer two thirds of the upper lid from the underlying tissues. This separation extends